**Education in the 21st Century:**

**Just-in-Time Learning or Learning Communities**

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**Abstract**

Surrounded by smart machines, there are those who envision a world in which learning is evolving into a self-paced process of finding information or learning skills just when and where they are needed. The flexible delivery of learning services to students and teachers through "anytime, anyplace" networking will, computer enthusiasts claim, revolutionize schools and universities. Some advocates of just-in-time information delivery systems take an extreme position claiming that textbooks, university faculty and courses will soon be obsolete (Twiggs, 1994). Twiggs argues that the widespread availability of self-paced learning materials will create a national learning infrastructure that will diminish the need for faculty designed courses and faculty-centered approaches to learning. The learner will no longer be guided by master teachers through "courses" of study. Instead students will independently access information from databases and multimedia sources to complete learning modules they organize. This information delivery is linked to the idea of lifelong learning, learner-driven learning and project based learning.

The notion that just-in-time learning will replace structured education massively undervalues the role of teachers in designing the "courses" of intellectual development and the role of others in forming conceptual knowledge. We need to be cautious about reducing education to the activity of moving haphazardly from one interesting project to the next collecting bits of knowledge and learning skills as needed. Education implies a plan that integrates learning into larger intellectual frameworks that will serve the learner in immediate and generative contexts. This requires dynamic teacher-student interactions around an integrated course of knowledge and skills, with the structure influenced by forces in the economy, academy and community. While technical tools can replace some of the routine tasks of delivering information at the moment of need, this work should not be confused with designing a "course" of intellectual development, providing intellectual guidance and monitoring intellectual understandings. Communication technology can widen the educational dialogue increasing access to other teachers, students, and professionals forming "learning communities" that extend beyond individualized learning and classroom teaching.

This paper examines the role of technology in reshaping education as we shift into the next century. I argue that just-in-time learning is based on a metaphor that cast learners in the role of highly knowledgeable consumers of knowledge. In doing so, there is a danger that the role of teachers and the larger community of learners will be minimized. Instead, I propose that it is formation of learning communities with extensive informational and human resources embedded in organized instructional contexts that is central in creating new educational designs. Rather than decrease the need for teachers, I see technology is increasing access to, and need for, teachers. Communication technologies is transforming classrooms into learning communities in which students learn and teach and in which teachers (some in the classrooms and some from distant locations) teach and learn. My central argument is that just-in-time learning technology will increase the need for skilled teaching and teachers, and not serve to marginalize teaching.

**Just-in-time Learning**

Just-in-time learning is a phrase borrowed from industry to describe the changes that have taken place in the communication and delivery of learning resources. In its most radical form, it suggests that teachers will become less important as active learners will be able to locate what they need, when they need it, from a worldwide showcase of information. The shift to just-in-time learning paradigms is used to justify investment in the development of modular learning units. I argue that we need to increase our investment in human resources, and in the professional development of educators, rather than in the development of modular, self-paced, educational units. In order to understand the dimension of this debate over how to plan for education in the future, it is instructive to draw out the metaphorical relationships of "just-in-time" product delivery to "just-in-time" learning.

The Metaphorical Relationships

Just-in-time delivery refers to a fundamental change in factory-consumer relationships. The traditional model--factory to warehouse to showroom via sales staff to consumer--has dominated market interactions from buying cars to coffee makers.

Recent advances in transportation and communication make it possible to change these patterns. Instead of producing many different models of products and stock pilling large inventory to meet the unknown needs of the consumer, just-in-time delivery means customizing product options to customer desires. It fills market demand efficiently without costly stockpiling of products which could become obsolete with new developments. Faster and more efficient technology for production, communication, and transportation, makes it possible for industry to respond rapidly to changes in demand for products or product options. A consequence of this process is that the knowledgeable salesperson is often eliminated completely or replaced by a person who can list the options but has no extensive understanding of the product. This places a greater responsibility on the consumer to understand the options, design, and use of products (Diagram 2).

Just-in-time learning is set in contrast to the factory model of knowledge acquisition in traditional models of education. The factory model of information delivery (Diagram 3 matches the traditional factory model (Diagram 1).

Knowledge is produced in universities and organizations (factories), stored in textbooks and learning materials (warehouses), distributed to schools (stores), and delivered to students (consumers). Teachers, like knowledgeable salespersons are cast in a role of matching the needs of the students with the information resources. In many cases, they adjust the timing and organization of the delivery of the information but accept the content as determined by others. The lines of delivery are marked by the single direction arrow in Diagram 3. The two-directional arrows represent the hierarchical system of information sharing. Students and teachers talk about classrooms learning; teachers, school administrators, parents and the community discuss school needs; administrators interact with suppliers; and suppliers talk with producers.

Just-in-time learning conjures up an educational system that responds rapidly and flexibly to changing societal needs. Concepts, ideas, theories, learning tools are "delivered" as they are needed to solve real-world problems. The Internet makes it possible for learners to have contact with knowledge producers and to access information when and were they need it with less dependence on schools or teachers to mediate the access (Diagram 4).

In both industry and education, there is a belief that ready access to primary information sources will eliminate the need for knowledgeable mediated guidance. These models assume a transformation of learners and consumers into individuals who understand what they need, where to find it, and how to use it. What is missing from these diagrams is the support system that makes this direct communication with primary sources effective.

Characteristics of Just-In-Time Learning

Just-in-time learning suggests a highly individualist model of learning with the following dimensions:

1. Learner-control
2. Time-independent and place-independent access
3. Functional use of information.

The help functions of many of machines and computer programs meet these three dimensions of just-in-time learning. When trying to format a document, run a statistical comparison, create a graphic effect, or remove a paper jam, computers often provide help menus or help "knowbots" that show the user how to accomplish their task in the moment of need. The presence of this form of just-in-time learning resources embedded in the machines reduces the need for extensive group training or expensive repair visits. But what happens when we extend this type of learning model beyond "training" to education? Can we assume that knowledge acquisition is a similar process?

What does it mean to have learner controlled, time and place independent access, and functional need, drive intellectual development? Examination of these dimensions with respect to school learning point to concerns over the use of the "just-in-time" metaphor to characterize changes that are taking place in education.

**(1) Learner-Control**

‘Just-in-time’ learning implies that the learner’s need is what drives the delivery of information. Educator reformers who use "just-in-time learning" are often those who advocate learner-directed, constructivist modes of learning in contrast to information delivery systems or programmed learning tutorials. They are not focused on delivery of information as much as on the skill that the learner must have to find the information that they need. Student learning is described as a process of constructing, elaborating and modifying representations of knowledge (Piaget, 1952; Bruner, 1961). In traditional classrooms (the factory model) decontextualized information delivery is the mode of instruction. In this system, students retrieve the information, but are unable to use it to solve problems or understand relationships. It is these shortcomings of the traditional system that are used to argue for an inquiry-based approach to learning. Constructivists argue that integrated learning directed by the students help them to understand why, how, and when to use information and tools (Springfield, Ross and Smith, 1996; Meier, 1995; Darling-Hammond, 1997; Ruopp, Gal, Drayton, & Pfister, 1993. Because students direct the learning, there needs to be access to extensive resources. Designing a comprehensive curriculum from multi-discipline, project-based activities is the challenge faced by many of the New American Design Schools, (Cohen & Jordon, 1996, Hunter, 1995, Goldberg & Richards, 1996; Campbell, et. al., 1996) as well as many online teacher development programs (Roupp et al, 1993, Math Learning Forums). What is missing in these descriptions is how the learner acquires the skill to be an expert consumer of learning resources.

Opponents of constructivist learning approaches claim that "learning-controlled," "project centered," or "theme based," instruction fails to provide strong content knowledge in any discipline. The result is that students do not know even the most basic elements of the different subject areas (Hirsh, 1996; Ravitch & Finn, 1987). Hirsch fears that these progressive ideas create an instructional context that lacks intellectual coherence. Instead, he calls for a more traditional approach to curriculum which emphasizes student mastery of a scope and sequence within a discipline--an ordered, logical sequence of foundational ideas, concepts and tools to be presented to students over a period of years. Basic skill educators are unsympathetic to constructivist notions that suggest the learner should control education. They place the teacher and national or state agendas as the central force in directing the course of learning.

This debate between directed and discovered learning, between Locke’s and Rousseau’s conceptions of the learner, between fixed and flexible characterization of knowledge delineates educational battles throughout this century (Kolberg and Meyer, 1972). Students need guidance and assessment by skilled teachers. Projects need to be placed in larger contexts. Students need help in understanding how their project work relates to the larger field and to the community of people who are involved in creating, organizing and preserving knowledge. Building knowledge is a community activity.

**2) Time Independent and Place-Independent Access**

Just-in-time learning is time- and place-independent. The learner can access information when and where it is needed. Computers linked to the Internet provide this flexibility of access because it connects to vast collections of information and tools. Any group or individual can make digital information (photos, sounds, text, images) available to anyone who wants this information, at any time, and from any place. This is the feature that leads some to suggest that teachers will no longer be needed to organize the learning experience (Craig, 1966; Twigg 1994). The claim is that students will "learn how to learn" and will be able to pursue their interests and projects independently, with little need for teachers.

It is this claim that just-in-time learning will make teachers obsolete that is challenged. Ready access to rich informational resources from many different perspectives *increases* the need for skilled educational direction from teachers. Students need to learn how to evaluate information and information sources, what other resources are available, and how their work integrates with that of others to create a comprehensive understanding of a field of study. Creating cross-discipline, project based learning requires exceptionally talented teachers who understand the scope and sequence of each discipline well enough to make sure that students are receiving a comprehensive education. Those who argue against constructivist learning have some valid concerns. However, the solution is not a return to "basics"--information delivery education. What is needed, instead, is a move forward to basics integrated with rich interconnected projects within knowledge building communities (Scardamalia and Bereiter, 1994, 1998).

Ultimately a good education is the result of interactions with good teachers. An effective way to accomplish this is by increasing both the number and quality of teachers and to utilize students as resources for each other. We need to create learning communities that will make it possible for many more people to participate in classroom interactions. Acknowledging the power of flexible, on demand learning tools and technology, this papers presents a very different structure for their use from that of many who advocate just-in-time learning.

**(3) Functional Use of Informational Resources**

Just-in-time learning suggests that knowledge is a stockpile of *discrete* ideas, concepts or tools that can be delivered as needed. The systemic relationships among skills and concepts are minimized in this way of thinking about knowledge. It also assumes that ideas only have value in terms of their functional use in solving specified problems. But knowledge is about reflection and debate as much as it is about solving practical problems efficiently. Knowledge is not built from the needs of individuals; it is a process of weighing many different perspectives, of thinking beyond what is needed for the current activity. Information resources need to be examined from the multiple perspectives of the community and analyzed in ways that lead to comprehensive integrative learning.

The notion that we will all become self-direct learners working with computer terminals to learn what we need to know undervalues the role of teachers and experts and of conflict and multiple perspectives. Experts open new avenues of inquiry, challenge the learner in new directions and encourage the process of evaluation and reflection. We can use the wealth of new tools for teaching and learning within communities working together to build knowledge.

The Internet is a stunning collection of global knowledge, with distributed control by experts and communities. This information is available to more people, more quickly, and with less effort. At a superficial level, this increases our independence from particular places and people. This is the point that is made by those who argue that just-in-time learning gives us a new way to think about education. At a deeper level, though, this enormous amount of information ultimately increases our dependence on each other. The Internet contains far more data than any one person can read, evaluate or use. We need to be a part of learning communities to build knowledge in ways that help us understand our world.

Just-In-Time for What?

The organic model of learning in which students take over the role of educating themselves with "just in time" learning modules is the 1990’s version of the free school movement of the 1960’s (Neill, 1970). It assumes that students know what they need to know, are motivated to learn, and can determine their own course of study. This assumption contrasts sharply with the traditional model of classroom instruction that is found in most U.S. schools (Cuban, 1993). In the traditional model, the teacher sets the course of learning (based on school, district and national frameworks) for a class of students who can all be taught, for the purpose of instruction, the same content and in the same way. Traditional classrooms operate on the implicit assumption that the teacher is dealing with each independent learner, but in a group context.

With the knowledge base rapidly expanding, the traditional model of teaching and learning is at a breaking point. There are far too many students for one teacher. There is far too much content for any single teacher to master. The tensions in this model are different at different levels of schooling. In elementary schools, where the focus is on the learners, the tension appears in finding a single teacher who can provide rich, extensive, multi-subject learning experiences. In the secondary education, the tension results from have a large number of single subject teachers working with different groups of students hourly. In these schools, class members are grouped by age and ability to be as similar as possible. They are expected to work independently to master the content in the curriculum.

This traditional model no longer serves the needs of a society rich in information and in need of citizens who know how use diverse talents in concert to solve complex problems. Just-in-time learning suggests that students can work more independently with less need of teachers. Instead, I argue that technology contributes to more *inter*dependecy then *in*dependence and a need for more skilled teachers.

**From Classrooms to Learning Communities**

The claim that "just-in-time learning" tools will make it possible for students to pursue independent learning within a computer-delivered personal learning plan is not consistent with changes that are taking place in our society. A team of representatives from industry, unions, government and education studied 15 jobs in five employment sectors to find the common skills necessary for success in these occupations (SCANS, 1991). The SCANS report for America 2000 describes three foundational (conceptual, problem solving, and personal) skills and a set of five competencies that were critical to job performance across diverse occupations. The competencies include learning how to work with people of differing talents in teams using resources, information, and technology to create shared understandings of systemic relationships and consequences.

Rather than using new communication and computer technology to further individualize learning, classrooms can be organized into learning communities with students, teachers, and community members all playing vital roles in directing the course of education. The premise that just-in-time learning should or will lead to more individualize learning is not the only possible outcome. The opposite is also possible--that these tools will transform classrooms into learning communities.

How is a Learning Community different from a class of students? What would it mean to involve students in learning communities? In this section of the paper, a traditional classroom is compared to a learning community. This is followed by a description of the new "power tools" and practices that help create this transformation. It is within this larger context of change that just-in-time learning tools have value.

What is a Class?

A "class" in mathematics or science is a collection of objects that share the same properties or characteristics. The word "class" is used to refer to a group of learners matched on characteristics that effect their learning, their knowledge base, their age, and their skill in learning. This grouping of students is an effort to create a homogenous class so that a teacher can talk to each student as if they were the only person. Each class member works independently to demonstrate what he or she has learned, with help between students viewed as cheating. Class rules and "discipline plans" are created to increase uniformity of actions. This effort to create uniformity has resulted in rigid ability tracking (Oakes, 1985). Even before some students are old enough to read the signpost, they will find themselves on paths that will not lead them to the futures they may later desire (Mehan, Villanueva, Hubbard, & Linz, 1996).

Students do not naturally fit into this rigid structure. They are different. They begin school at different ages, some with very different backgrounds and experiences, and all with unique strengths and weaknesses. They learn at different rates and need to have different experiences.

What is a Learning Community?

Knowledge construction in our society is rarely done in isolation. People in a field work together building on the ideas and practices of the group. Culture and cognition create each other (Cole 1985). Learning increasingly takes place in "communities of practice" (Lave & Wenger, 1991; Ruopp, Gal, Drayton, & Pfister 1993; Pea & Gomez 1994; Dunbar, 1996). A community of practice is a group of people who share a common interest in a topic or area, a particular way of talking about their phenomena, tools and sense-making approaches for building their collaborative knowledge, and a sense of common collective tasks. These communities of practice may be large, the task general, and the form of communication distant, as in a group of mathematicians around the world developing math curriculum and publishing their work in a set of journals. Alternatively, they can be small, the task specific, and the communication close, as when a team of teachers and students plan the charter of their school.

The community of practice in schools can be a number of subject or topic specific "learning communities." Learning communities share a way of knowing, a set of practices and shared value of the knowledge that comes from these procedures. Communities support different ways for novices and experts to work in the same system to accomplish similar goals. Community members are recognized for what they know as well as what they need to learn. Leadership comes from people who can inspire others to accomplish shared goals.

How is education different when students are members of learning communities? Consider these comparisons in Table 1.

|  |  |
| --- | --- |
| **Class Structure** | **Learning Community** |
| Homogeneous Groupings | Heterogeneous Grouping |
| Class Discipline | Community Organization |
| Competition | Collaboration |
| Knowledge Delivery | Knowledge Construction |
| Teachers Centered | Student Centered |
| Independent, individual work | Interdependent, teamwork |
| Expertise flows from 1-to-many | Expertise flows in many directions |

Table 1: Differences between the Organization of a Classroom

and a Learning Community

Learning communities recognize that students arrive with different skills, at different ages, with different experiences and interests and build this diversity into the learning context. In a learning community, students learn to work in teams and learn how to make teams work. The accomplishment of the team is primary and each member of team contributes in some way to the outcome. This makes students in a learning community *inter*dependent. They build from each other’s strengths develop a sense of competence and empowerment in areas where they are most motivated or skilled, and can pull others who are weaker in these areas up with them. Distributed knowledge is a building block for such learning communities. (Levin, Riel, Miyake, & Cohen, 1987; Brown and Campione, 1994; Pea and Gomez, 1994; Pea, 1994, Dunbar, 1996, Levin 1977).

Some reform efforts are currently experimenting with transforming graded classrooms to multi-age and ability learning centers.For example, the Los Angeles Learning Center demonstrates effective patterns of student learning in multi-age communities with differing expectations based on the evolving skills and abilities of each of the students (Springfield, Ross & Smith, 1996).

The most important difference between classrooms and learning centers revolves around the control of new learning opportunities. When students are participants in learning communities that include a network of people who organize around a specific issue, problem, or debate, the resources and direction of the learning are less predictable. If the learning community is exploring the origins of human behavior or the shape of an equation, they are not limited to the people who are in the room who are all at the same "level" of understanding. The inclusion of many people with differing expertise makes the direction of the community neither under the complete control of the teacher, nor under the complete control of the learner. Instead, the control of learning is an interactive process that develops as the community works together to create shared understandings. All members of the community, including the teachers, are learners and teachers model skilled learning.

Internet technology provides a rich format for the larger community to participate in the education of the next generation. Past technologies (print, photography, film and computers) have made it possible for many people to share their ideas with students without actually entering the school, but only in a one-way transmission mode of communication. With communication on the Internet, it is possible for students to interact with many more people and ideas, in some cases through multi-media interaction. Students, teachers, experts, and resources around the world can pose challenging questions to each other, point to valuable resources and provide instant responses to the questions posed. Transforming the classroom into a learning community makes it possible for many more people to be a part of the learning process in an open and continuing dialogue. Using the metaphor "learning communities" in place of just-in-time learning highlights this different approach to education.

Let’s consider the changes in instructional technology that makes this transformation from learning in classrooms to learning communities possible.

**Evolving Power Tools for Learning**

Traditional instructional delivery strategies involve a combination of readings, lectures, models, observations, and film. In traditional models of instruction, learning is not just-in-time from a student’s perspective. Rather it is a carefully choreographed sequence designed to "cover" a broad range of material in a given discipline.

In the past decade, the tools for learning have significantly changed. These tools, in turn help to create an image of how the learning environment will change (Riel, 1997). Not only do they bring students different resources, (pictures from Mars, transcripts of global news conferences, newspapers from around the world, images from live cameras), but these tools make it possible for students to learn in different ways. Students are currently engaged in group projects that are very difficult or impossible with the resources found in traditional classrooms. No single person can provide the rich complex of knowledge and skills that might be needed by a community of students. A good library can provide some of these resources but computer and communication technology multiplies the possibilities.

These learning tools, while very powerful, do not minimize the role of the teacher. A new set of educational tools will not, by themselves, provide the wide systemic perspective that characterizes quality education. These tools can make it possible for students to participate in communities that extend beyond their school building. Skillful teachers will need to help students learn how to evaluate information and information sources and to place what they are learning within the larger context of intellectual development.

This section of the paper explores the evolution of classroom activities that embed "just-in-time-learning" tools within learning communities. Evolving tools contribute to new possibilities for learning. The structure of future learning environments will be determined by how students, teachers and the community use these educational tools (See Table 2).

|  |  |
| --- | --- |
| **Past Tools for Learning** | **Promising Power Tools for Learning** |
| Textbooks and worksheets | Primary Sources and student created materials |
| Linear text student writing | Hypertext multimedia productions |
| Models and materials | Virtual creatures and simulations |
| Direct observations | Tools for remote observations |
| Educational films broadcast reality | Virtual worlds interact with reality |
| Teacher delivers lectures | Many "expert" voices in classroom |
| Student reports to teacher on learning | Student generated lessons for others |

Table 2: The Evolution of Instructional Tools

From Textbooks to Primary Sources

Textbooks are an accommodation to economic necessity. While it is preferable to use primary source materials in classroom, neither school nor class libraries are extensive enough to contain the necessary collections. Textbooks blend many different points of view and information together into one source that can be provided to each student.

With access to the Internet, primary source data of all kinds can form the basis of instruction and research economically. With the help of these and other multi-media resources, teachers can use primary sources in their classroom presentations. Instead of worksheets that reinforce the secondary interpretations of textbooks, teachers can design student projects and study questions that encourage students to develop analytical and interpretive skills. All students can search libraries from around the world for primary sources that they can learn to interpret and analyze for themselves. They use multimedia resources such as film clips, sound files, and still images to create new understandings of our history and ourselves.

For example, a teacher can use resources like the online Library of Congress (www.loc.gov), a national treasury of memory, reason, and imagination of Americans. Until recently, accessing documents from the Library of Congress was extremely time consuming. First you have to appear in Washington, D.C. and go to the Library reference section. After locating a reference for an item and requesting it, one often waits hours before it is delivered to the reading room. If another person is using it, it cannot be used. With digital access the content material, text, photographs, sounds, videos and documents can be ordered in seconds from any location in the world and many people can use the same materials at the same time.

Using these resources, students can be asked to adopt the role of different historical figures and reenact discussions and debates from other periods. To understand history, students need to understand the frame of mind of the people who lived in different periods; primary sources make it possible for students to engage history directly. Furthermore, telecommunication projects invite the collaborative investigations and participation of students from around the world. These students, by nature of their various geographic locations and cultures, will have very different perspectives on historic events, and their multiple perspectives offer a richer tableau for testing ideas and theories.

From Linear Text to Hypertext

Linear texts are increasingly being replaced by hypertext with links to extensive information. Students with access to encyclopedias on the computer have tools for finding information that would have been difficult to locate in the past. While traditional test-based indexes helped students find key terms or concepts, students can now search for any or every occurrence of a word in the collection. Internet search tools, though still primitive for educational use, give students access to more information than could ever exist in a single school library.

Students can use hypertext to organize their learning, but they can also use hypertext as a form of expression. Writing in hypertext is a new skill. It is conceptually different then sequential writing. It allows for a different form of interaction between author and reading and larger communities of people. Writing collaboratively with a larger community of people who care about a topic is a powerful lesson in group problem solving and thinking (Scardamalia & Bereiter, 1994).

Students learning how to use and compose in hypertext are participating in new evolving forms of communication (Koschmann, 1994; Pea, 1994). They are learning to write in a format that is integrated with other forms of expression including color, formatting, graphics, photography, audio, and video. These skills are increasingly valued as the ability to work with current technological advancements require specialized communication skills such as graphic design and multi-media hypertext and video production. These are the "basic" skills for the communication age.

From Hands-On Models to Virtual Simulations

There is no doubt that the use of three-dimensional models in schools help students understand concepts, relationships, functions and structures. When students have hands on experience with objects that they can touch, move, and assemble, they gain a better conceptual understanding. Math manipulatives are standard learning tools recommended in most curriculum framework or guides. Students use blocks, dice, triangles and rulers to understand number relationships. Science labs and scaled models help students visualize what is hidden beneath skin or rotating far off in space. In social science students build models of missions, forts, castles and other communities of the past. These multi-sensory constructions serve as concrete representations of ideas that are complex and interlinked.

The computer extends our ability to model. With the ability to create virtual objects with complex properties and relationships, we can begin to simulate functions and processes that are invisible without these tools. Simulations make it possible for students to see and experiment with the way atoms bond, wind flows, or planets orbit.

One example is the [Virtual Frog Project](http://summit.stanford.edu/creatures/) by Researchers at Stanford University. Over the Internet students can access the virtual frog, a visual 3-dimensional rendering of different systems that constitute a frog. In classroom dissections of "real" frogs, students see only the remains of a dead frog. With a virtual frog, they can make the skin transparent and stain food to watch the digestive process. Virtual creatures model internal processes and interactions with their environment. These relationships are not visible through the process of examining the skin, bones and organs of a dead frog. This technology enables students to experiment with the relationships between the structures and functions in these virtual creatures. For example, students can be challenged to breed or engineer a frog that will jump higher or further than that of their peers. Doing this would require an understanding of how size and length of bones interact with the development of muscle tissue. Hypotheses can be formed, tested, and analyzed using these virtual objects.

From Direct Observation to Remote and Extended Observation

It is, and will remain, important for students to use their observations of the world as part of their investigations. Dewey, concerned by the *rapid growth of technology* of the last century, feared that direct learning experiences would be replaced by a poor substitute, book learning:

As societies become more complex in structure and resources, the need for formal teaching and learning increases. As formal teaching and training grows, there is a danger of creating an undesirable split between the experience gained in direct association and what is acquired in school. This danger was never greater than at the present time, on account of the rapid growth in the last few centuries of knowledge and technical modes of skill. (Dewey, 1916, p. 9)

Today these same words are echoed by a new generation of educators. Today, however, the concern is that *computers,* rather than books,will replace direct learning experience (Stoll, 1996; Oppenheimer, 1997). Used appropriately, however, computers, like books and other resources, can be companions in the investigation of reality. Projects designed today, using the computer as a research tool, send students into the physical and social world to collect observations, measurements, surveys, and other data using appropriate scientific tools. Telecommunication networks make it possible for them to then exchange, analyze, and discuss this information with their peers from around the world. In the [GLOBE](http://globe.gov/) project, students from around the world collect, compare and analyze data concerning air temperature, air pressure, wind speed, precipitation, and other environmental measurements (Means, et al., 1997). Visualization tools make it possible for their data to be displayed in the same full color maps that they download from science centers (Pea & Gomez, 1994). Students in [Learning Circles](http://www.iearn.org/circles) often create projects that require their peers in other countries to conduct investigations, collect surveys or design interviews with people in their communities (Riel, 1992). In the [Global Lab Project,](http://hub.terc.edu/gl/gl118.html) students locate, measure, and mark an open area of land near their school. They share measurements and investigations both above and below the surface of the earth with students from around the world, each working on the same size section of the earth. These examples describe learning environments supported by computers that *increase rather than decrease* student direct experiences with their physical and social world.

As computers become smaller and more portable they become valuable field guides and research tools in the laboratory and in the field. Students can use microcomputer-based measurement and monitoring devices for collecting and analyzing data (Rohwedder & Alm, 1997). Using laptop computers and a set of monitoring devices, students can collect, record and graph their data on temperature, relative humidity, light intensity, pressure, and voltage right on the spot. More in-depth analysis and descriptions can occur back at the school site.

Tele-Robotics make it possible for students to [direct a telescope](http://www.eia.brad.ac.uk/rti/automated.html) to look out in space from their classroom, [tend a garden](http://telerobot.mech.uwa.edu.au/) located in Austria or experiment with light and heat in a [model house](http://telerobot.mech.uwa.edu.au/) in Australia. Students can also participate in [electronic field trips](http://www.att.com/edresources/wt/travel.html) using a range of tele-robotic devices to explore the ocean floor or view out into space. Scientists and researchers are reaching out to schools, inviting students to be part of their learning communities. In this past year, students were able to collectively reserve time on the [Hubble telescop](http://quest.arc.nasa.gov/hst/index.html)e, work with scientists exploring the [Monterey Bay](http://www.virtual-canyon.org/), or follow a team of adventurers as they traversed the rainforests of Mexico, Guatemala and Belize in search of [lost Mayan cities](http://www.mecc.com/internet/maya/maya.html) and clues for saving the environment.

Scientists are using new technology extend their observational range- to look out in space, under the seas, and into the microscopic world. Small, inexpensive sensors may make it possible for students to place micro-sensors down a snake hole or up a tree in a bird nest. This would enable them to make observations that are simply not possible when they rely only on their own senses. These observational tools would make it possible for students to share what they find locally with those in other environments in the same way that scientists share their data with distant colleagues, building knowledge in [collaborative learning communities](http://www.iearn.org/webtour/2/vision.html).

From Broadcasting Video to Creating New and Virtual Worlds

Photos, filmstrips, slides and video have given students the opportunity to learn about a range of topics that extend and expand textbook learning. While typically motivating, these are passive media. Teachers worry that students may be watching but not thinking, not actively engaged with the materials they viewing. In contrast, when students create their own films and video reports, either originally or based on their involvement with the content they have viewed, their involvement in the content area and learning process is much greater.

Virtual reality adds additional interactive options to the learning environment, making it possible for students not only to see what exists, but also to place themselves in different settings. In these worlds, they can make choices, and see the consequences of their actions. For example, students can now watch dynamic videos taken by remote vehicles that explore the deep canyons of the Monterey Bay off the coast of California. Students are encouraged to use these materials to create their own narrated explorations. In a few years, they may be able to assume the identity of one of the inhabitants of this underwater world and see if they can survive in a simulated bay. This "Virtual Canyon" would not simply be a game. It would be a visual database of current information about this complex ecosystem in which students could manipulate objects, make choices and view consequences of their actions. Virtual environments which model real life may be, in some senses, more real than the videotape representations that we now see as real.

From Student Reports to Students as Teachers

With better access to resources, students can become experts on different topics. They can share this expertise not just by completing assignments given to the teacher, but by creating resources for others’ learning, using today’s technological production tools. Powerful examples of this can be seen in the library of websites created by students as part of the [ThinkQuest Contest.](http://io.advanced.org/thinkquest/tq97.winners.html) Since it 1996, students from around the world have been forming partnerships and creating educational environments for their peers. Examples include the following student-created products:

[EduStock: Economics and Investment: A Stock Market Simulation](http://io.advanced.org/thinkquest/library/3088.html). Students can create their own stock portfolios and experiment with making and losing money in real time with the free real-time stock market simulation on the Web. Once students create their portfolios they are saved and updated every 20-minute period with the actual values from the exchange. This is a great math activity for students of all ages. It also provides an easy way for anyone to experiment with personal investments.

[Design Paradise: A Simulation Game of Land Use](http://io.advanced.org/thinkquest/library/2111.html) As CEO of a major development company, students are challenged to create a balance among the needs of industry, environment, and citizens to create a stable and prosperous economy on an island. The island of Kauai, in the state of Hawaii, serves as the "laboratory." The game can be played for hours as the island takes shape. The game players are given a numerical score on their success as a developer and they also receive "happy points" based on the satisfaction of the inhabitants of their island paradise.

[From The Ground Up: A Guide to C++ and The Online Point of View-Ray](http://io.advanced.org/thinkquest/library/3074.html) These tutorial are interactive lessons helping students learn more about the technical tools that are create the web. Students who master these tools will be able to create new forms of learning and artistic expression in the networld.

[Anatomy of a Murder: A Trip through Our Nation's Legal Justice System. The drama](http://io.advanced.org/thinkquest/library/2760.html) begins with the body of an unidentified young woman found in a car on a deserted desert road by a police officer. The officer has to secure the scene and wait for a team that will begin the work of collecting evidence from this crime. While you read, optional mood music plays. Each chapter of the story provides the foreground. Fact sheets give the background legal work that explains what is taking place at the scene, in the police station, the lawyer's office, or the court system. Every detail of police and lawyer work has been researched to help the readers understand what happen behind the scenes from the time the murder is committed to the end of the trial. While the story is fiction, the education is real.

[Welcome to Himalayas - where earth meets sky](http://hyperion.advanced.org/10131/). This site explores Himalayan altitudes, lands, geologic past, trekking,flora and fauns, environmental problems, provides an atlas, traveler's corner, guided tour and quizzes for users to test their knowledge.

Students and teachers of music, art, chemistry, history, culture, war, math, and physical education will find that students have provided high quality educational experiences that other can share. These contest winning entries show what students can create using computer tools, and how they can be creators of information, teachers as well as learners. And, as every teacher knows, teaching is one of the best ways to learn.

When students take part in programs like "Facing History and Ourselves" and the [Holocaust/Genocide Project](http://www.iearn.org/iearn/hgp.html) they learn to look back into history and then look at their own actions in a new light. This provides a resource for teachers and students to study conflict and effective strategies for conflict resolution.

[Cyberfair](http://gsn.org/) involves students in "service learning" as part of a worldwide contest. Students form partnerships with different segments of their community and help them by designing a web site for them. Students learn about their community and how to use technology in the service of community goals. As part of the contest, students must evaluate web sites created by other schools. Participating in this process of peer review helps student to understand the process of evaluating and validating information placed on the Web.

These projects and web sites, created by students from around the world, represent the best efforts of students working collaboratively to teach each other. But there are many ways students can help teach within their local communities as well. Students who are comfortable with mathematics and understand mathematical concepts quickly can help students who need additional time and assistance to help them see a relationship. Often these exchanges are helpful to both parties. A student who finds it easy to create ideas but harder to edit them can be paired with a student who is a better editor than creator, creating a symbiotic learning relationship. These relationships within the learning community can both increase the human resources for teaching and expand the possibilities for learning.

From One Expert to a World of Experts

Communication tools make it possible for people anywhere in the world to be a part of a classroom lesson. Increased human resources extend the topics that students can explore. Electronic field trip opportunities make it possible for students and teachers to join teams of researchers, scientists, and technicians exploring a distant region such as Mars, a rain forest, or Antarctica. Additionally, teachers can invite distant "[team-teachers](http://www.iearn.org/circles/mentors)" from any field, with any expertise, to work in the classroom. For example, subject matter experts are matched with teachers in programs such as the "Electronic Emissaries." Adult mentors are also matched with students to provide support and direction in school learning through the Hewlett-Packard Mentor Program. The Writers-in Electronic-Residence program matches professional authors with classrooms providing students with feedback on their writing. In Passport to Knowledge projects, scientists schedule regular videoconferences to discuss ideas and concepts over live broadcasts and in online projects.

Distance education is providing flexible online materials that share information in a different format than traditional classroom lectures. Videotaped demonstrations and explanations give learners have a high degree of control over the time, location and method of study, and make it possible for teachers to work with students in distance locations. Multiple modes of delivery can augment time spent in class and communication technology can make it possible for group work to take place from individual terminals. For example in the Collaborative Visualization Project (Pea, 1994) students can get help from scientists by clicking on their images. Using videoconferencing, they can share their computer display and discuss their data and ideas.

**Charting the Course of Learning--A Communal Activity**

Many of the properties identified as just-in-time learning--

* student centered projects
* ease of access to instructional tools and tutorials
* authentic tasks

--are important ingredients in the design of new learning environments. However, the premise that the overall effort is to individualize instruction is not the only possible outcome. Increasingly we are coming to understand learning as a social interactive process.

With the emerging Networld and with it more powerful communication tools, the classroom walls no longer need to isolate students from the community. As we have seen from the many examples, students are now being of service to government agencies and community groups. Increasingly, there are opportunities for partnerships with industry. Students are forging new relationships with companies and industries involving students in "service learning" relationships. This development challenges educators to use these new tools and to structure these new relationships so that student learning is primary, with service as an important outcome.

New partnerships are forming between industries that market to children and schools. Some provide opportunities for students to work for companies in tele-apprentice relationships from the classroom. An open question is can we create an integration of students with the business community without returning to the abuse and exploitation of children that characterized the last century? The media brings stories of how these new tools are leading to new forms of child endangerment, pornography and abuse. We need skilled teachers to help design new learning environments alert to the possibilities of student exploitation as knowledge workers.

The tools that are new making a difference in classroom are those that help students to connect and create. The connections are both inside and outside of the classrooms where experts of all ages can be a part of the resources for learning. And the ability to create is what makes it possible for every student to share what he or she discovers with others. Teachers are likely to continue to play a vital role in helping students to shape, evaluate, and share ideas.

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(Footnotes for Print copy)

1. For more information on this project see (http://summit.stanford.edu/creatures/)
2. The GLOBE project was created by Vice President Al Gore to increase student understanding and participation in environmental issues. For more information on GLOBE, see http://globe.gov.
3. Learning Circles are collaborative partnerships where students from many different regions design and participate in projects organized around a curriculum theme. These projects often involve extensive community and cultural research. http://www.iearn.org/circles.
4. Global Lab is project organized by TERC in which students share data on a tract of land near their school as a way to understand important issues in environmental science. http://hub.terc.edu/gl/gl118.html.
5. Onset Instruments, P.O. Box 3450, Pocasset, MA 02559; phone: (508) 563-9000).
6. For more information on using telescopes on the Internet see: http://www.eia.brad.ac.uk/rti/automated.html.
7. To view the telegarden and experiment with the telerobots for planting and watering the seeds, see http://telegarden.aec.at/cgi-bin/knapsack/html/info.html.
8. Mag-Nify Virtual Science and Technology Centre hosts a research project for students on heating and cooling using a small scale model of a house. From anywhere in the Networld, students can turn on different numbers of light bulbs and a fan. Students measure the heating and cooling effect. One of the goals of this site is to experiment with remote operation of tools. http://magnify.educ.monash.edu.au/measure/computer\_house.htm.
9. To see a list of these electronic field trips and adventure learning opportunities now available on the Internet see "Electronic Travel" in Riel (1997) Transportation for the Mind, http://www.att.com/edresources/wt/.
10. Live from the Hubble Telescope was a Passport to Knowledge Project http://quest.arc.nasa.gov/hst/index.html.
11. The Monterey Bay Virtual Canyon Project is an NSF funded partnership between schools, the Monterey Bay Aquarium, and the Monterey Bay Research Institute (www.virtual-canyon.org).
12. The MayaQuest Project was one of a number of excellent projects sponsored by MECC (www.mecc.com/internet/maya/maya.html).
13. See the last section of Learning Spaces in the Networlds of Tomorrow for more ideas on how this might be used as an educational activity (http://www.iearn.org/webtour/2/vision.html).
14. ThinkQuest is an international contest that challenges students to work in teams creating teaching materials for other students (http://io.advanced.org/thinkquest/tq97.winners.html).
15. For more information on the Holocaust project see (http://www.iearn.org/iearn/hgp.html),
16. CyberFair is a contest organized each year by the Global Schoolhouse Network (http://gsn.org)
17. To see a list of these electronic field trips and adventure learning opportunities now available on the Internet see "Electronic Travel" in Riel (1997) Transportation for the Mind, (http://www.att.com/edresources/wt/travel.html).

For a listing of different types of online mentoring programs and links to them see http://www.iearn.org/circles/mentors